Design of the Radio Frequency Section of a Multiple Beam Klystron working in the J-band Frequency Range

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Abstract: *The multiple beam klystrons (MBK) offer some distinct advantages over their single beam versions including higher average power, relatively lower operating voltages, higher bandwidth and low individual beam current. In this paper the design of the radio frequency (RF) section of a multiple beam klystron working in the J band frequency range is presented. The RF design and simulation has been carried out using a commercially available three dimensional electromagnetic design code. A cold test model of the RF cavity has been fabricated and its resonant frequency has been characterized. Design of the individual cavities, simulation results of the beam wave interaction as well as the frequency characterization of the fabricated cavity is presented in this paper.*

Keywords: Radio frequency section; Beam wave interaction; Multiple beam klystron; Cold testing;

Introduction

The MBK amplifiers use a number of electron beams separately propagating in parallel to increase the total available current [1]. The individual beams interact with the input RF fields in the input cavity and passes through of a series of resonant cavities. Between the cavities, the individual beams are transported through separate beam-tunnels to reduce space-charge effects. This allows the total beam current to be high, while individual beam perveances are low. The main difficulty in designing the RF cavities of a MBK is to achieve sufficient shunt impedance for efficient beam-wave interaction and symmetric coupling over all the beams in the input and output sections at a given frequency. Symmetric coupling can easily be obtained using multiple couplers, but in this case the complexity of the input and output circuit increases manifold.

The design of the RF circuit for the proposed MBK is done in such a way that it remains compatible to a pre-designed electron gun [2]. Due to the dimensions of the gun, the radius of the circle on which all the beam-centers should lie is fixed. Therefore, it is necessary to design the RF cavity at the desired frequency with a diameter sufficiently larger than 7.5 mm to accommodate the four beamlets. Moreover, the input and output cavities should have symmetrical coupling over all the four beamlets without the use of multiple couplers. All these design objectives have been achieved by a careful and meticulous design approach [3]. For the electromagnetic simulation, the commercially available three-dimensional code CST EM Studio has been extensively used [4].

Design

Intermediate cavity: In order to get the resonant frequency in the desired frequency band while maintaining the cavity dimensions compatible with the predesigned gun geometry, coaxial type cavity geometry has been considered. Four nose cones have been inserted inside the cavity for transmission of the four beamlets. Fig. 1 shows the electric and magnetic field patterns of the desired resonant mode.

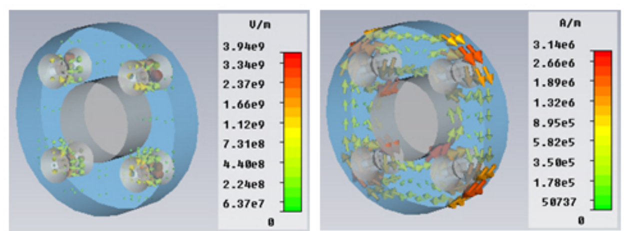

Figure 1. Electric and magnetic field distribution of the desired resonant mode.

From Fig.1 one may note that the electric fields are nicely concentrated around the nose cones, as desired.

Input and output cavities: The input and output cavities have been considered to have slot coupling to provide the RF input as well as to extract the RF output. If the coaxial cavity (Fig.1) is directly coupled to a reduced height waveguide via slot coupling, a severe problem of uneven

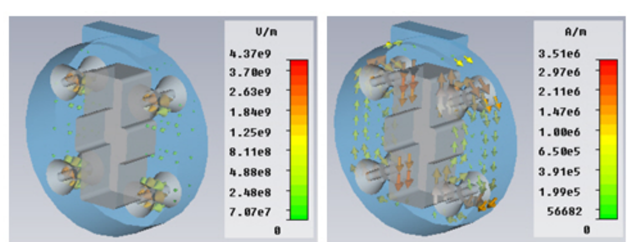

Figure 2. Electric and magnetic field distribution of the resonant mode of the input /output cavities.

coupling over the beamlets occurs. In this case, it has been observed that the beamlets near the coupling slot get strongly coupled through the slot, but the beamlets far from the slot remains mostly uncoupled. To eliminate the problem, the central conductor geometry has been optimized to get an overall symmetrical coupling over all the beamlets [Fig. 2].

Beam-wave interaction simulation: In order to investigate the RF amplification, extensive beam-wave simulation has been performed using the time domain particle-in-cell (PIC) module of the CST EM studio. Total six numbers of cavities (including the input and output cavities) have been considered for the simulation. The RF input has been applied through the waveguide port of the input cavity and the output signal growth has been observed at the waveguide port of the output port.

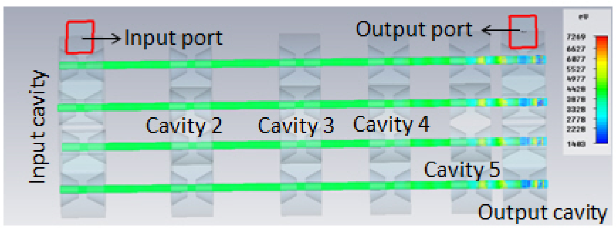

Figure 3. Snapshot of the electron trajectory (energy plot) after 100 ns of PIC simulation.

Fig.3 shows a snapshot of the electron trajectory after 100 ns of PIC simulation. Here, the color code denotes the electron energy variation. One can note the wide variation in electron energy at the output cavity, denoting the energy transfer at the output cavity gaps.

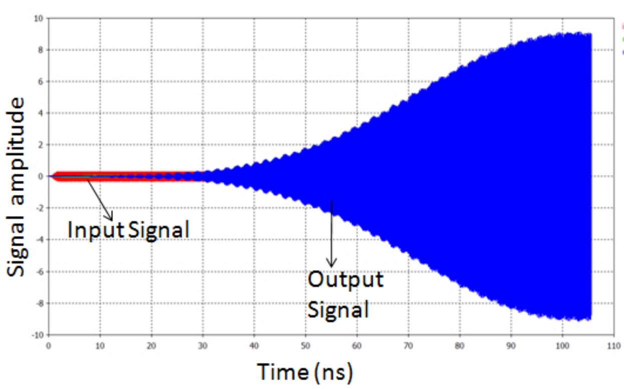

Figure 4. The input and output RF signals observed at the input and output ports respectively.

Fig.4 shows the observed input and output RF signal amplitudes plotted against simulation time. After 30 ns of simulations, a steady growth of the output RF signal amplitude is indicated. From the figure, it can be further observed that the growth of the signal tends to saturate after 100 ns. From the time signals, it can be further observed that the gain is about 30 dB for the considered RF section.

Frequency characterization of the RF cavity: To validate the simulation, a test cavity has been fabricated and characterized with the help of a vector network analyzer. The cavity has been excited by a set of probing antenna: one is to feed the RF signal and the other one to receive the RF through two diagonally opposite nose cones. Repetition of this measurement configuration by putting the receiving antenna in other beamlets allows characterizing the resonant frequency of the cavity as well as the coupling of the RF over all the four beamlets. The fabricated cavity parts and the measured reflection and transmission coefficient are shown in Fig.5. A good agreement between the simulated and measured resonant frequency has been observed.

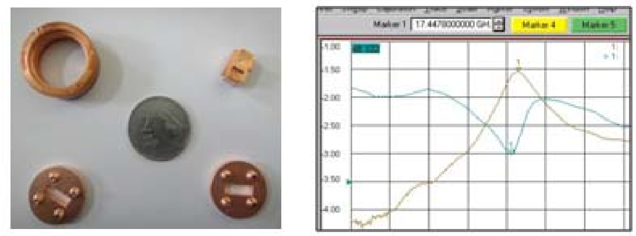

Figure 5. Cold test model of the RF cavity and its frequency characterization.

Conclusion

RF design of a multibeam klystron working in the J band frequency range has been presented. Its beam wave interaction simulation results using 3D PIC code have been presented. The frequency characterization of the RF cavity has also been carried out to validate RF design of the cavity.

References

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